TOURISM IMPACTS ON CORAL REEFS:

INCREASING AWARENESS IN THE TOURISM SECTOR

UNEP

TOUR OPERATORS INITIATIVE
FOR SUSTAINABLE TOURISM DEVELOPMENT

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The opinions expressed in this report are solely those of the author and not necessarily those of UNEP

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Tom van't Hof, Saba, April 2001

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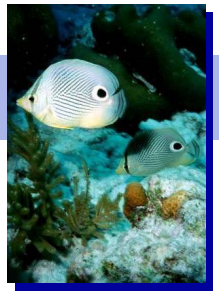

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2. EXECUTIVE SUMMARY

2.1 Tourism impacts

The tourism sector is of major economic importance in the Caribbean region, both in terms of foreign exchange earnings and in terms of employment. Since Caribbean tourism is primarily associated with beaches and the sea, there have been -and continue to be- impacts from tourism on the coastal environment, including the coral reefs.

Tourism impacts on coral reefs include both direct and indirect impacts. Activities with direct impacts are: snorkelling, diving and boating, which can cause direct physical damage to reefs, and fishing and collecting, which can contribute to over-exploitation of reef species and threatening local survival of endangered species. Indirect impacts relate to the development, construction and operation of tourism infrastructure as a whole (resorts, marinas, ports, airports, etc.).

Direct physical damage from snorkelling and diving has been the subject of extensive study and is relatively well documented in the literature. The damage inflicted by divers and snorkellers consists mostly of breaking fragile, branched corals or causing lesions to massive corals. Most divers and snorkellers cause little damage, only a few cause relatively much damage. Research indicates that reef degradation and change of community structure occurs once a certain level of use by divers and snorkellers is exceeded. As a rule of thumb it is recommended that the level of 5,000 to 6,000 dives per sites per year should not be exceeded. Training and briefing of divers and snorkellers will greatly help to reduce negative impact.

Physical damage from anchors and especially boat groundings can be severe. Anchor damage is proportional to the size of the boat (*i.e.* weight of the anchor and length of anchor chain) and is further dependent on the type of coral community. Recovery of coral damage from boat groundings is slow. Anchor damage can be avoided to a large extent by installing permanent moorings, designating anchorages and providing adequate information on anchoring and mooring.

Although fishing is a cause of decline in reef fish stocks throughout the Caribbean, the direct role of tourism in this decline is most likely not significant. Indirectly, tourism increases the demand for seafood and does have an impact of on reef resources. Collecting of marine souvenirs by tourists is probably insignificant but there still is a market for marine curio in response to a certain tourist demand. The demand can definitely be decreased by increased awareness.

Tourism-related sources of sewage pollution include resorts and, to a much lesser extent, recreational vessels. There is evidence that a very large percentage of the sewage generated by hotels is discharged in coastal waters without adequate treatment. The main impact of sewage pollution is nutrient enrichment, which favours certain species (algae in particular) at the expense of corals. The different impacts of nutrient enrichment from sewage pollution on corals *in general* have been well studied; those from sewage pollution from hotels and recreational vessels have not.

The studies indicate that the impact of sewage pollution depends much on the level of treatment before discharge and the degree of flushing at the point of discharge.

Tourism is not generally a source of petroleum hydrocarbon pollution, other than at a small scale when oil or fuel spills from recreational vessels and marinas occur. The effects of petroleum hydrocarbons on corals has been studied for quite some time and there is evidence that chronic oil pollution is more harmful than a single exposure, and that dispersants and emulsifiers used to combat spills are more toxic than oil alone.

Coastal development and the construction and operation of related tourism infrastructure cause increased runoff and sedimentation. Sedimentation is generally considered one of the main reasons for reef degradation. Increased sediment loading of coastal waters increases turbidity, reduces light levels and leads to stress on corals, usually expressed by “bleaching” of corals. Heavy sediment loading may also cause corals to suffocate and die. Other documented impacts of sedimentation on corals include lower growth rates, reduced productivity and reduced recruitment.

Tourism is obviously a source of large amounts of solid waste. The impacts of solid waste on coral reefs depend very much on the method of disposal. If disposed of inappropriately, leaching of toxic substances may impact negatively on corals. Of particular concern is the “accidental” waste –plastics in particular- that is blown into the ocean from beaches or vessels and has a detrimental effect on corals and other marine life.

The impacts of tourism on coral reefs are significant, but they are also compounded by other impacting factors that are not easily discernable from those of tourism. This does not mean that we must disregard the impacts of tourism activities. On the contrary, the tourism sector and government agencies involved in tourism development must try to eliminate or reduce those impacts that *can* be controlled, even if there is no 100% proof that a certain impact is directly related to a tourist activity.

2.2 Key actors

The key actors in the tourism sector are the tourists and those who cater to the tourists, whether directly or indirectly. Caribbean tourists can be roughly divided in those who desire sea, sun and fun as the primary qualities of their destinations and those who are more interested in the natural and cultural qualities of the destination. The level of awareness relating to coral reefs between the two groups is obviously quite different.

Among the direct caterers we distinguish three main groups:

- Travel agents, tour operators and transport companies;
- Hotels and restaurants;
- Water sports operators.

The awareness relating to coral reefs is generally low among the first group and among restaurants. The awareness among hoteliers and water sports operators is much higher, but there appears to be some “finger pointing” in that increased

awareness is needed in other sectors rather than in their own. The awareness among the water sports operators and their clients in the *primary* dive destinations is much higher than that in others. Consequently, the benefits of increased awareness will vary, depending on the destination and the size of the operations, but they can be substantial. The marina and yachting sector is somewhat of an exception in this category, with awareness among the marina operators mostly low and higher among yachtsmen, especially among private yacht owners.

The indirect caterers include politicians decision makers, private investors and lending institutions that enable tourism development. This is a diverse category, with an awareness level that is not necessarily low, but with interests guided by political, economic and financial incentives, rather than by sound ecological guidelines.

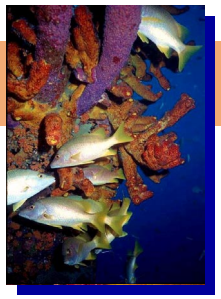
2.3 Awareness campaign

Based on the analysis of impacts and actors, recommendations were formulated for an awareness campaign. The guiding criterion was to target awareness at those groups whose awareness was relatively low and where benefits would be potentially high.

This resulted in the selection of three main target groups:

- The individual tourist;
- The water sports operators and their clients;
- The politicians/decision makers, private investors and financial institutions.

The message to the individual tourist and the operators will attempt to reduce direct physical impacts from tourist activities on coral reefs, while the messages to the latter category will be geared towards incentives that will make a change in behaviour worthwhile economically and politically.



3. INTRODUCTION

Coral reefs are under threat. The scientific community is in agreement about it and the press talks about it. Fifty-eight percent of the world's reefs are potentially threatened by human activity. Not counting the Pacific, 70 percent of all reefs are at risk. Overexploitation and coastal development pose the greatest potential threat (Bryant et al. 1998).

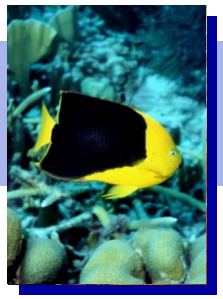
Coral reefs are not only under threat; they are actually suffering from decline and degradation due to a combination of natural and anthropogenic factors. Some of these anthropogenic factors are related to tourism. At the same time tourism is of great economic importance to most Caribbean states and territories. For some smaller island territories, tourism may well be the mainstay of the local economy. Because tourism in the Caribbean is dependent almost entirely on coastal resources, most development takes place in the costal zone and most of the impacts occur in the coastal zone. Impacts from tourism activities include both direct physical impacts (such as diver damage and anchor damage), as well as indirect impacts from resort development and operation, and development of tourism infrastructure in general. Impacts from tourism can often be reduced by raising awareness and changing behaviour. The purpose of this report is to provide the background information for an awareness campaign that will reduce the negative impacts of tourist activities on coral reefs.

This report is organised in three main sections:

- Section 4 describes and analyses the impacts of tourism activities on coral reefs. This analysis is entirely based on a literature survey and an extensive bibliography is given in section 7. It becomes apparent that there is a large body of scientific literature on the direct impacts of tourism, and much less literature that links indirect impacts of tourism with coral reef degradation. Nevertheless there is ample evidence of detrimental effects of such indirect impacts that may be associated with tourism.

- Section 5 provides an analysis of the key actors in the tourism industry. Who are they; what is their respective level of awareness, and what are the potential benefits from increased awareness and changes in behaviour of these actors. The analysis is based on a limited survey, but mostly on the consultant's experience and opinion.

- Section 6 pulls the results of the two previous sections together and attempts to answer the questions: "What messages should be sent to the main actors in order to raise awareness and change behaviour, and through which channels should these messages be disseminated?"



4. TOURISM ACTIVITIES AND THEIR IMPACTS ON CORAL REEFS: DESCRIPTION AND ANALYSIS

4.1 The tourism sector

The tourism sector is of significant economic importance for most states and territories in the Wider Caribbean region, most notably so in many of the island states. In 1990 Caribbean tourism earned $ 8.9 billion (Holder, 1991). For the seven (island) states in the top 20% of those dependent on tourism (average of 89 rooms per 1,000 inhabitants) average tourism earnings were 59% of GDP. For the seven (island) states in the next 20% (average of 36 rooms per 1,000 inhabitants) average tourism earnings were 48% of GDP (Potter, 1996, using data from Hoagland, *et al.*, 1995 and Caribbean Tourism Organization, 1995).

A recent issue of Caribbean Latin American Profile estimates that SCUBA diving in the Caribbean will generate $ 1.2 billion by the year 2005. Some 60% of international SCUBA diving tourists currently choose Caribbean destinations for their holidays (Kelly Robinson, pers. comm.).

It is unquestionable that, apart from the climate, the coastal zone with its beaches and adjacent ocean and associated opportunities for relaxation, recreation and in-water activities, are the main factors in attracting visitors to the island states of the Caribbean. The influx of visitors, their activities in the coastal zone and the infrastructure required to cater for these visitors, have diverse and multi-faceted environmental and cultural impacts which are described by many authors (*e.g.* see UNEP, 1997). This report is restricted to a description and analysis of the tourism activities which impact on coral reefs[1].

4.2 Impacts of tourism: overview

In the Caribbean, 25 out of 30 countries have reported tourism as being a factor in the deterioration of reefs (Wells, 1985, cited in Craik *et al.*, 1990). Cortes (1997) notes that tourism is an important source of coral reef degradation and eventual destruction for the coral reefs of Central America. In what ways is tourism contributing to reef degradation?

Tourism activities, which have an impact on coral reefs, can be divided in those that have a direct physical impact and those that impact indirectly on coral reefs. Direct impacts include for example breaking of corals by snorkellers and divers, anchor damage, and boat groundings. Indirect impacts are related to tourism development in general and include such aspects as sedimentation from construction, sewage and

[1] The term “coral reefs” is used in a broad sense in this report, including both biogenic carbonate structures (bioherms) composed of the skeletons of reef-building corals and other organisms, as well as other structures and assemblages which include reef-building corals and other reef-dwelling organisms.

solid waste disposal from tourist facilities, increased demand for seafood, etc. An overview of activities and their impacts is given in Tables 1 and 2.

ACTIVITIES WITH DIRECT IMPACTS	ACTUAL AND/OR POTENTIAL IMPACTS
Snorkelling	Physical damage (breakage, lesions) Kicking up sediment
SCUBA diving	Physical damage (breakage, lesions)
Motor boating and yachting	Physical damage from anchoring Physical damage from boat groundings
Fishing	Contribute to over-exploitation of reef fish stocks Compete with local fishers
Collecting	Threatening local survival of rare species (*e.g.* shells) Contributing to over-exploitation and competing with local fishers (*e.g.* conch and lobster)

Table 1. Tourism activities with direct impacts on coral reefs.

ACTIVITIES WITH INDIRECT IMPACTS		ACTUAL AND/OR POTENTIAL IMPACTS
Resort development and construction		Increased sedimentation
Resort operation	Sewage disposal Fertilizer runoff Irrigation	Nutrient enrichment
	Solid waste disposal	Leaching of toxic substances from inappropriate waste disposal Litter (especially plastics)
Seafood consumption		Over-exploitation of high-priced resource species (snapper, grouper, spiny lobster, conch).
Demand for marine curio		Exploitation of rare/endangered/vulnerable species of shells, black coral, turtles.
Construction of artificial beaches and beach replenishment		Increased sedimentation (from sand removal and/or from beach instability)
Airport construction or extension		Increased sedimentation from dredging and infilling
Marina construction		Increased sedimentation from dredging
Marina operation		Pollution from inappropriate disposal of oils and paint residues Pollution from fuelling
Motor boating and yachting		Nutrient enrichment from sewage disposal Pollution from fuelling
Cruise ships		Nutrient enrichment from illegal sewage disposal Litter from illegal or accidental solid waste disposal

Table 2. Tourism activities with indirect impacts on coral reefs.

4.2.1 Physical damage to corals

In this section we will discuss the direct physical damage to corals that can result from snorkelling, SCUBA diving, and motor boating and yachting.

4.2.1.1 Physical damage from snorkelling and diving

Snorkelling is one of the easiest ways to enjoy and admire the shallow coral reef environment. It is available to virtually anyone who is able to swim. A snorkeller will typically "float" on the surface above the corals and thereby *should* have minimal impact on the reef. However, damage from snorkellers tends to occur in shallow water where snorkellers can stand up, and it tends to occur in particular with inexperienced snorkellers who feel uncomfortable with their equipment and behave more "clumsily" than experienced snorkellers. The impacts from snorkelling can best be described as:

- Trampling of corals by standing up
- Fin kicking causing breakage of corals (mostly fragile, branched species)

Damage inflicted by SCUBA divers is usually associated with a lack of buoyancy control skills and inadvertency, resulting in accidental interactions with coral such as bumping into coral and kicking coral with fins, causing breakage or lesions depending on the type of coral. Certain behaviour such as standing on coral heads or holding onto corals may be due to ignorance about the fragility of corals and the potential impact of contact.

Several authors have researched and documented snorkeller and diver damage. It is often difficult to distinguish such damage from natural damage or other forms of human-induced damage (for example, see Rogers *et al.*, 1988). This points to the need to design research methods that will target a specific issue and eliminate compounding factors. Hawkins and Roberts (1993*b*) and Scura and Van't Hof (1993) have applied such methods by comparing heavily dived and little dived areas and by looking at gradients of impact along a line of decreasing recreational activity.

Rogers *et al.* (1988*a*, 1988*b*) monitored coral breakage at two reefs in the Virgin Islands National Park and Biosphere Reserve (VINP), as well as individual Elkhorn coral colonies (*Acropora palmata)*. They attributed broken coral branches to careless snorkellers, boat strikes and swells. They noticed divers and snorkellers bumping into corals or standing on them, and overturning corals to reach lobster. Even in the absence of major storms or other stresses, only 10 of 50 tagged Elkhorn coral colonies remained undisturbed over a 7-month period of observation. Rogers *et al.* (1988*a*) report that at Trunk Bay in VINP, where a snorkelling trail was established in the early sixties –receiving 170,000 visitors annually by 1986- ".... the trail has deteriorated substantially as a result of people standing on corals, breaking coral branches while snorkelling, and removing organisms as souvenirs."

Tilmant (1987) and Tilmant and Schmahl (1981) studied the impact of recreational activities on buoyed reefs in Biscayne National Park, Florida. Each buoyed reef received three or more times as much use as its control. The most frequent recreational activities were snorkelling and spear fishing. The mean frequency of damaged coral encounters ranged from 35 to 140 per 30-minute count. Although significant differences in damage between buoyed reefs and controls did occur at

some sample points, such differences did not follow a consistent pattern that could be readily attributed to human use. Incidence of damage to soft corals was much higher than that to hard corals. They recognized that, since the level of recreational use on the reefs studied was relatively low (no more than 1,500 people per reef per year), the impacts may be more severe at higher levels of use.

Talge (1991) studied the behaviour of snorkellers and SCUBA divers in the Looe Key National Marine Sanctuary, Florida, in terms of the number of interactions between divers and coral. The interactions she observed were:

1) Hand on the coral to steady or help gain control
2) Kicking or brushing with the fins
3) Standing on corals
4) Grabbing corals (especially soft corals) to pull themselves through the water
5) Rubbing against coral with any part of the body
6) Hitting coral with the SCUBA tank or other pieces of equipment
7) Creating sediment clouds

The most frequent interactions were “finning” and “push-off”. The average number of interactions per diver is ten per dive. Snorkellers had significantly less interactions than SCUBA divers, divers without gloves had fewer interactions than divers with gloves, and females had fewer interactions than males. Over two-thirds of the interactions were with hard corals. This contrasts with the findings of Tilmant and Schmahl (1981) and may well be due to the selection of the study sites, one being comparatively richer in soft corals than the other. Coral breakage included only 0.6% of all incidents. This author also expressed concern with increase in nitrogen concentration of the water by divers urinating over the reef. This concern has not been substantiated by further research.

An experimental study by Talge (1992) in the Looe Key National Marine Sanctuary, Florida, consisted of weekly “touching and “finning” selected corals at two intensities. Weekly touching had no detectable lasting influence on the health of 11 species of corals, either visibly or histologically. Based on an average of 10 interactions per diver, she calculated that 4-6% of the live coral area is touched weekly. However, as a small percentage of divers have much more frequent interactions, she recommended that the touching ban in the Sanctuary be maintained.

Scura and Van’t Hof (1993) and Dixon *et al.* (1993) describe diver impact in Bonaire, Netherlands Antilles. A comparison of sites receiving high levels of use, intermediate levels of use and controls (reserve sites closed to diving) indicated that percent hard coral cover is significantly lower at high-use sites than at control sites, while species diversity is higher at high-use sites than at controls. At intermediate-use sites no such differences were found. The study also suggests that impact is decreasing with linear distance from the centre of activity (in the case of Bonaire the dive boat moorings). Percent coral cover and species diversity increase with distance from the mooring. The findings led to the postulation of a “threshold” hypothesis that diver impact becomes quickly apparent when use exceeds a level of 4,000-6,000 divers on a dive site per year.

Hawkins *et al.* (1999) repeated the study of Scura and Van’t Hof (1993) three years later. They found a decrease in coral cover at both control and dived sites, except at one of the sites labelled as high-use in the 1993 study. Their study showed that dive sites suffered no greater loss of coral cover than control sites in the three-year

period. However they found a distinct difference in community structure between high-use and control sites. The proportion of massive corals that make up total coral cover decreased at both high-use and control sites, but the decrease was much greater at high-use sites (19.2% *vs.* 6.7% decrease). The proportion of branching coral increased 8.2% in high-use sites compared to 2.2% in control sites, with coral diversity and species richness showing a similar pattern. They conclude that there has been an increased disturbance of Bonaire's reefs over the three-year period between the studies, with greater disturbance in high-use areas than at control sites. A reduction in cover by massive species is also reported in Connell (1997) for Buck Island, St. Croix, US Virgin Islands. Although no explanation is offered for the decline, it is noteworthy that Buck Island is a location, which is subjected to heavy recreational use.

Several studies on diver and snorkeller damage have been conducted in other parts of the world. Although Indo-Pacific reef structure and species composition are different from that of most Caribbean islands (extensive reef flats and more branching and foliaceous species), the results of these studies are nevertheless of value and useful to relate here.

Allison (1996) researched snorkeller damage to reefs in the Maldive Islands. The study showed a positive correlation between the distribution of broken corals and snorkelling activity on the reef at Vihamanaafushi. The study concludes that: "....the observed breakage is important because of potential reduction of the aesthetic appeal of the reefs to tourists, and degradation of the reefs' ability to sustain the islands they protect and nourish." The author advocates, amongst others, programmes to educate and train users to reduce damage, and to develop information packages and simple effective data collection methods suitable for amateurs. Networks of dive and tour operators could be used as the implementation vehicle for such programmes.

Hawkins and Roberts (1993*b*) studied the effect of trampling by SCUBA divers and snorkellers on reefs flats of coral reefs in Egypt. They found significantly more damaged corals and loose fragments of live coral in heavily trampled areas than in little-trampled areas. Percentage of bare rock and rubble was significantly higher, while percentage of live coral cover and number of hard coral colonies were lower. Coral colonies were also smaller in trampled areas compared with control areas. In summary, heavy trampling by divers appears to alter the coral population structure of the reef flat. Although the Western Atlantic reefs do not have extensive reef flats as occur in Indo-Pacific reefs, some Caribbean islands have experienced or continue to experience the effect of divers and snorkellers treading on coral. Buccoo Reef in Tobago is probably the most infamous example of the destruction caused by reef walking (see Rogers *et al.*, 1988*b*). Where shore diving is practiced, divers and snorkellers will also have some impact on shallow reef areas by trampling.

Hawkins and Roberts (1992*a*, 1992*b*, 1993*a*, 1993*b*, 1994) compared heavily dived and un-dived areas in Egypt and found significant differences in levels of damage. Numbers of broken hard coral colonies, live loose coral fragments, reattached fragments, abraded colonies, and part-dead colonies were higher in dived areas. They concluded that divers cause significant damage to benthic communities on the fore-reef slope. Their findings suggest that damage accumulates rapidly when a new site is opened up for diving, with impact stabilising after a certain level of use had

been reached. The three study sites received between 5,000 and 13,000 dives per year. Hawkins and Roberts (1994) suggest that dive sites at Sharm-el-Sheik in Egypt can accommodate 10,000 to 15,000 dives per year without serious degradation.

Epstein *et al.* (1999) compared populations of the hard coral *Stylophora pistillata* at a site that had been closed to the public for six years with two nearby sites, open to the public, in Eilat, Northern Red Sea. The main results of the study indicate that: (1) live coral cover was three times lower at the open sites than at the closed site; (2) there were significantly more small colonies (recruits) at the open sites and significantly less large-size colonies; (3) the average number of broken colonies was three times higher at the open sites. They interpret the lower breakage level in the closed site as a sign of the effectiveness of the closure, but they also conclude that a no-use policy is not sufficient for protecting small reef areas.

Jameson *et al.* (1999) developed a Coral Damage Index (CDI) to assess the extent and severity of physical damage to coral. Sites are characterised as “hot spots” if in any transect the percent of broken coral colonies is 4% or more, or if the percent cover by coral rubble is 3% or more. In a study of four diving sites off Hurghada and Safaga, Egypt, in the Red Sea, 40% of the transects surveyed qualified as “hot spots”. The relatively large number of hot spots in shallow water suggests that most of the damage was caused by anchors dragging across the reef. They conclude that the diving carrying capacity of the sites is being exceeded by large amounts.

Muthiga and McClanahan (1997) compared the impact of visitor use (diving and snorkelling) in heavily used sites and less frequented sites. They found no significant differences in coral cover or bare rock and rubble between sites, nor differences in coral species composition and diversity. However, there was significantly more damage to coral in the high-use sites, as evidenced by the number of broken, abraded, and broken and reattached coral colonies. Greater damage as observed in shallow than deep areas, which may indicate that snorkellers have more impact than SCUBA divers. Differences between the results of this study and those in the Red Sea may be explained to a large extent by the much higher visitation levels in the Red Sea.

Davis *at al.* (1995) observed diver interactions in the Julian Rocks Aquatic Reserve in Eastern Australia. Thirty divers were observed for about 30 minutes each. The number of diver contacts ranged from 2 to 121 (average 35 contacts per dive). More than 50% were contacts made with fins. Only 7.2% of contacts resulted in noticeable level of damage. The majority of damaging contacts were with hard corals, with lesser damage inflicted on sponges and turf algae. More experienced divers (those with more than 100 logged dives) made significantly less uncontrolled contacts than less experienced divers.

Harriott *et al.* (1997) conducted a similar study of diver contacts at four other locations in Eastern Australia (Heron Island and Lady Elliott Island in the Southern Great Barrier Reef, and Gneering Shoals and Solitary Islands in sub-tropical Eastern Australia). There was a large range in the total number of contacts per diver per site, with a few divers having a disproportionate impact. This coincides with the findings of Rouphael (1995). The maximum number of contacts ranged from 192 at Gneering Shoals to 304 at Solitary Islands. There was a significant difference between the mean numbers of contacts between sites, ranging from 31.3 at Heron Island to 121.2 at Solitary Islands. The mean number of *coral* contacts follows more or less the same

pattern, but there is no significant difference between sites in coral breakage. The mean number of corals broken per dive ranged from 0.6 at Heron Island to 1.9 at Solitary Islands. Most contacts were made by fins and 78% of coral breakage was caused by fins. Differences between the number of contacts and coral breakage per site were attributed to:

1. Greater awareness among divers at Heron Island and Lady Elliott Island (located within the Great Barrier Reef Marine Park), because of the awareness campaigns by the Great Barrier Reef Marine Park Authority and pre-dive briefings at these sites.

2. At Solitary Islands and Gneering Shoals, divers actively explored the small invertebrate fauna and thereby spent more time close to the bottom where they were more likely to make contact with corals.

Apart from the direct physical impact from diver and snorkeller contacts, such as breakage of coral and inflicting lesions, there is also some evidence that damaged corals show reduced growth rates (*e.g.* Liddle and Kay, 1987, and Meesters *et al.*, 1994).

The studies on diver impact have given some indications –although far from unequivocal- on ecological carrying capacity of reefs for recreational diving. At Julian Rocks Aquatic Reserve in Eastern Australia, with the majority of the 20,000 dives made per year occurring in a small area, it is believed that the ecological sustainability may be exceeded (see Harriott *et al.*, 1997). Hawkins and Roberts (1994) estimated that the most heavily used sites at Sharm-el-Sheik, Egypt, received between 35,000 and 50,000 dives per year and feared that that level was exceeding the carrying capacity of the reefs. They suggest that sites can withstand 10,000-15,000 dives per year without serious degradation. Epstein *et al.* (1999) feel that the number of dives for Eilat and Egyptian reefs far exceed the maximum sustainable diving levels as calculated by Dixon *et al.* (1993) and Hawkins and Roberts (1997). Scura and Van't Hof (1993) postulated that in Bonaire, Netherlands Antilles, there might be a threshold of 4,000 – 6,000 dives per site per year, above which reef degradation becomes quickly apparent. In a study comparing diving intensities and impact in Egypt, Bonaire and Saba, Hawkins and Roberts (1997) advocate to maintain use at levels below 5,000 – 6,000 dives per site per year, which is very close to the estimate of Dixon *et al.* (1993). Chadwick-Furman (1997) estimates the threshold for diving in the US Virgin Islands at only 500 dives per site per year. As suggested by Hawkins and Roberts (1997), the notion of carrying capacity is elastic rather than fixed and depends on other factors, such as the level of diver education and briefing, or adverse impacts from tourism development practices in general and construction in particular.

SUMMARY AND CONCLUSIONS

- Many studies on diver and snorkeller impact on coral reefs have been conducted throughout the world.
- The results of these studies are not unequivocal, mostly because of differences in methodology and study sites.
- The majority of divers and snorkellers appear to cause little damage; a few cause a lot of damage.
- Most damage consists of breaking fragile, branched corals, or causing lesions to less fragile, massive corals.
- There are indications that, once a new site is opened up for diving and snorkelling, the initial physical damage is high but levels off after some time.
- Once a certain level of use is exceeded (the level may differ from one place to the next and depend on the type of coral community), degradation of the coral reef and alteration of the community structure becomes evident. As a rule of thumb, the level of 5,000 – 6,000 dives per site per year should not be exceeded.
- Adequate training of diving skills and briefing on the fragile nature of the coral reef environment will promote responsible behaviour of snorkellers and divers and helps to minimise damage.

Box 1. Summary and conclusions diver and snorkeller damage.

4.2.1.2 Physical damage from motor boating and yachting

Physical damage to reefs and reef corals from motor boating and yachting can be caused by anchoring or boat groundings and has been described by several authors.

Rogers *et al.* (1988) surveyed 186 boats during a three-month period in 1987 in the Virgin Islands National Park and Biosphere Reserve (VINP). Of those, 32% were anchored in seagrass and 14% in coral communities. Of the anchors found in coral 27% were causing minor damage and 12% were causing moderate to severe damage. The average size of the boats anchored in the park was 44 foot. The authors note, however, that an increasing number of about 200 foot long cruise ships begin to use the park waters with the potential of much more severe anchor damage. Not long after their 1987 boat survey, Rogers (1991) and Rogers *et al.* (1991) describe an incident whereby a 440-foot ship dropped anchor on a reef, caused a scar of 128 m long and destroyed virtually all living organisms in an area of about 290 m^2. Eighteen months after the incident the scar is still very conspicuous. Rogers *et al.* (1991) also describe another incident whereby a mini-cruise ship of about 200 foot long violated park regulations by anchoring in about 4 m depth and damaged coral communities over an area of 5,300 m^2. Since the ship drew almost 3 m, the prop wash dislodged small corals, gorgonians and sponges from the substrate and caused heavy sediment loading. Rogers (1991) estimates that 30,000 boats anchor in the park waters each year.

The grounding of the M/V Wellwood on Molasses Reef in Florida in 1984 resulted in a 70-100% loss of live coral cover over a 1,282 m^2 area. Half of that area sustained reef framework fracture damage (Hudson and Diaz, 1988). Although the Wellwood

was a freighter, the example is nevertheless mentioned here because very similar damage could result from the grounding of a cruise ship.

The M/V Vetranic, a 475 foot freighter, went aground in 1998 on Pulaski Shoal, a coral reef in Fort Jefferson National Monument, Dry Tortugas, Florida, affecting an area of 16,000 m^2 (mentioned in Rogers *et al.*, 1991).

In 1987 the freighter Mari Boeing ran aground on the reefs of Bermuda. Storm waves shifted the ship on the reef during three months before she was salvaged using blasting. The directly damaged area was estimated at 440,000 m^2, with a peripheral zone of 25-50 m wide with a reduced population of surviving hard corals (Smith, 1985).

Tilmant and Schmahl (1981) report that at least six boat groundings occurred during a three-year study of recreationally used reefs in Biscayne National Park, Florida. These groundings resulted specifically in damage to large coral colonies that reach relatively close to the surface.

Reef degradation as a result of anchor damage and/or boat groundings is also a concern in Anguilla, Bahamas, Bermuda, Bonaire, British Virgin Islands, Cayman Islands, Honduras (Roatan), Trinidad and Tobago, and US Virgin Islands (Rogers, 1985).

SUMMARY AND CONCLUSIONS

- The impact from anchor damage is dependent on the size of the boat (which determines the weight of the anchor and whether or not a combination of rope and chain or all chain is used). It is furthermore dependent on the type of coral community: branched and foliose corals will be damaged much more easily and by smaller anchors than massive corals.
- The impact from boat groundings can be severe and not only destroy nearly all living organisms in the affected area, but also fracture the reef framework.
- Recovery from boat groundings is slow and it is unknown if the original community structure will be restored.
- Most anchor damage can be avoided by installing permanent moorings and by designating specific anchorages for larger ships, while providing adequate information on such moorings and anchorages to users.
- Boat groundings can be avoided by navigational buoys and channel markers, but will probably continue to occur as a result of human error.

Box 2. Summary and conclusions boating damage.

4.2.2 Overexploitation of reef resources

Overexploitation of reef resources results from unsustainable fishing and collecting practices in general and may not be considered an impact of tourism *per se*. However, tourists can contribute to the effect by engaging in fishing (usually sport

fishing) at their destination, by collecting shells, corals or other reef invertebrates, and by creating an increased *demand* for seafood and marine curio.

4.2.2.1 Fishing

Bohnsack (1993) reviewed the impacts of fishing on coral reefs. Direct impacts include the removal of organisms and habitat damage from destructive fishing practices. Indirect impacts can result from the removal of important components of the ecosystem, such as predators and herbivores, which can disrupt ecological relationships. Fishing can reduce population abundance, lower average fish size and age structure, and change species composition. Fishing tends to selectively remove the larger individuals because of their greater value for food, income and sport.

Although reef fish population declines have been widespread and dramatic in many instances (see for example Bohnsack, 1993; Rogers, 1985), the relative role of tourism in this decline – either from tourist fishing activities or from increased demand for seafood – is unknown. However, it is fairly safe to assume that tourist fishing will hardly target reef fish, but rather pelagic species and will thus have a minimal effect on population decline of reef fish. Increased demand for seafood is a more likely factor impacting on reef fish populations and coral reefs in general. Grouper, snapper, spiny lobster and conch are popular items on the menus of Caribbean hotels and restaurants. Tourists will usually not be aware of local restrictions, such as size limits and closed seasons, and, where those restrictions are insufficiently enforced, tourists may be served undersized or out-of-season produce and thus unknowingly contribute to over fishing and population declines.

4.2.2.2 Collecting

In her review of Caribbean coral reef degradation, Rogers (1985) mentions only one area (the US Virgin Islands) where coral collecting is considered a human-related stress factor. Although the review does not cover all Caribbean states and territories, this is nevertheless an indication that coral collection is not a serious problem in the Caribbean region. Most information on coral and shell collecting is from the Indo-Pacific region and relates to trade rather than to collecting by tourists. Simmons and Associates (1994) write: “The collecting of shells and coral souvenirs, either by tourists, or by locals for resale to tourists continues to have an impact on the environment in some destinations. Fortunately this practice is decreasing and is generally discouraged by those working in the tourism industry.” Since most in-water activities of tourists are organized or supervised, we will assume that collecting may occur incidentally but is not a factor of any significance.

Marine curio, including species protected by local regulations or international law, continue to be offered for sale at several Caribbean tourist destinations. This demonstrates that there still is a demand for such products. However, with the increasing effectiveness of the Convention on International Trade in Endangered Species of wild fauna and flora (CITES) and with the Protocol on Specially Protected Areas and Wildlife (SPAW) having entered into force, the demand is likely to decline further. Informing tourists on the provisions of CITES and SPAW will be especially effective in this respect.

SUMMARY AND CONCLUSIONS

- Fishing is a cause of serious decline of reef fish populations in most of the Caribbean.
- The direct role of tourist in this decline is probably insignificant.
- Tourism contributes indirectly to the decline by creating an increased demand for seafood.
- Collecting of marine curio by tourists is probably insignificant.
- Tourism continues to create some demand for marine curio, but this demand seems to be decreasing.
- Greater awareness among tourists about the provisions of CITES and the SPAW protocol will further reduce the demand for marine curio.

Box 3. Summary and conclusions fishing and collecting impacts.

4.2.3 Nutrient enrichment

Coral reefs are particularly susceptible to sewage pollution because of the delicate ecological balance maintained among a large number of species. The natural low levels of nutrients in tropical seawater are partly responsible for maintaining that balance. Sewage pollution disturbs that balance by nutrient enrichment, which will favour certain species, usually at the expense of reef corals, and will lead to alteration of community structure (e.g. Marszalek, 1987; Grigg and Dollar, 1990; Maragos *et al.*, 1985). Other effects of sewage pollution include toxicity (from toxic materials or toxic by-products from pesticides, herbicides or heavy metals contained in sewage), sedimentation (suspended solids), high biochemical oxygen demand, and hydrogen sulphide generation (Grigg and Dollar, 1990; Pastorok and Bilyard, 1985). However, most of the impacts from sewage pollution on coral reefs reported in the literature relate to the nutrient enrichment rather than to toxic effects. The literature suggests threshold levels for dissolved inorganic nitrogen of 1.0 mM and for soluble reactive phosphorus of 0.1 mM (see for example Lapointe *et al.*).

Other impacts of sewage pollution include a decline in growth rate of corals (in particular due to high concentration of suspended particulate matter; Tomascik and Sander, 1985), reduced calcification, and reduced settlement of coral larvae (Ward and Harrison, 1997).

In her survey of coral reef degradation in the Caribbean, Rogers (1985) identified sewage as one of the human-related stresses in 9 of the 25 islands or areas for which information was available.

There are several sources of sewage pollution related to tourism activities, including both point- and non-point sources of pollution, *viz.* discharges by recreational vessels, discharges of untreated or partially treated sewage by tourist resorts, seepage from septic systems and cesspits, and runoff or seepage of partially treated sewage used for irrigation (the latter may also contain fertilizers and herbicides). Clearly, the level of impact depends on the level of treatment of the discharged sewage and the degree of flushing occurring at the point of discharge.

4.2.3.1 Nutrient enrichment from sewage disposal by recreational vessels

Simmons and Associates (1994), in their study of the impact of tourism on the marine environment of the Caribbean, note that "….the impact of liquid waste from yachts has been poorly studied in the Caribbean region. While it is very likely to have an effect on water quality in lagoons and semi-enclosed bays, its impact is probably small or negligible in open bays with adequate flushing." Talge (1992) also touches on the issue of nutrient enrichment by diver activities and boat effluents. She raises the question: "…. But are the amounts significant and do they remain over and around the reef long enough to fertilise reef communities?" These questions have remained unanswered to date.

Although there is little doubt that sewage pollution leads to nutrient enrichment, which will favour species that outcompete corals and result in alteration of community structure (see introduction in 4.2.3), there are no scientific studies that demonstrate the link between these negative effects and sewage disposal from recreational boats. This statement must not be interpreted as an encouragement to allow disposal of raw sewage by recreational vessels. On the contrary, nutrient enrichment should be avoided wherever possible. The problem with eliminating sewage disposal from recreational vessels is that there must be a legal requirements for such vessels to have holding tanks, which in turn requires pumpout facilities in ports and marinas as well sewage treatment plants.

This problem is exemplified by the situation in the US Virgin Islands. The Department of Planning and Natural Resources expects that in the long term all vessels over a certain size will required to have holding tanks (the legislation is already in place), marinas will be required to have pumpout stations, and live-aboard vessel will be required to dock at marinas. All parties concerned recognize that the problem needs to be addressed, but critics state that before these requirements should be put in place, other factors need to be considered, namely, the relative contribution of vessel-generated waste to overall sewage disposal, the capacity to treat sewage, health hazards, and oceanographic characteristics such as currents and flushing (Simmons and Associates, 1994).

Theoretically cruise ships could contribute to nutrient enrichment by illegal discharges of untreated or improperly treated sewage. With the MARPOL Convention entering into force in 1988, this has become highly unlikely, especially while moored or anchored. Also, most cruise ships now have state-of-the-art on board waste processing facilities (see Simmons and Associates, 1994, for a more detailed discussion). Cruise line companies can be expected to do their utmost to maintain a good environmental track record.

4.2.3.2 Nutrient enrichment from sewage disposal by tourist resorts

The general impacts from sewage pollution as described in the introduction (4.2.3) can obviously also result from sewage pollution by resorts. Simmons and Associates (1994) mention that 80-90% of the sewage generated by land-based tourism operations is discharged in nearshore coastal waters without adequate treatment. This shocking figure is mentioned again in a study by the Panos Institute, based on an interview with the Caribbean Tourism Organization, CTO (Panos Institute *et al.*,

1996). However, studies that document the specific impacts of sewage pollution from resorts are limited.

Bell (1991) describes the impact of wastewater discharges from tourist resorts in the Great Barrier Reef, Australia. Two of the most visited islands, Hamilton and Green Island, have discharged virtually untreated sewage in the sea for quite some time. The coral communities at Green Island have been largely replaced by algae and seagrasses. He also recognises the impact of discharges of secondary treated sewage and sludge from Townsville on the coral reefs of Magnetic Island, just off Townsville. He expects seepage from sewage on Magnetic Island to be disastrous for the already stressed corals. He concludes that tertiary treatment of sewage will be necessary to achieve acceptable levels of nutrients (after dilution) in the discharged effluent. In comparing these findings with the Caribbean, we must realise that mean background phosphate levels for the waters outside the Great Barrier Reef are higher than those reported for the Caribbean.

Van Woesik *et al.* (1991) examined the response of coral communities to effluent discharge on Hayman Island, Green Island and John Brewer Reef in the Great Barrier Reef Marine Park. Except in the immediate vicinity of the sewage discharge outfall, they found no impact from discharge of secondary treated sewage from the resort on Hayman Island. On Green Island sewage from septic systems is subject to primary treatment before discharge. They attribute the increase in seagrass beds to nutrient enrichment from sewage discharge. At John Brewer Reef Floating Hotel (removed in 1989) treated sewage was transported and discharged 5 km off the reef and the only effluent discharged was brine from the desalination plant. Overall, coral cover increased in the vicinity of the hotel and the authors conclude that there was no detrimental impact of its placement or operations. They suggest that the impact of sewage discharges on coral communities is mostly dependent on the level and quality of treatment.

SUMMARY AND CONCLUSIONS

- The most deleterious effect of sewage pollution is nutrient enrichment, which favours certain species (algae in particular) at the expense of corals.
- Tourism-related sources of sewage pollution include resorts and, to a much lesser extent, recreational vessels.
- A large percentage of sewage generated by tourist resorts is discharged in coastal waters without adequate treatment.
- The impact of nutrient enrichment from sewage pollution in general has been well studied, the specific impact of sewage pollution from resorts and recreational vessels only to a limited extent.
- The impact of sewage pollution depends largely on the level of treatment and the degree of flushing at the point of discharge.

Box 4. Summary and conclusions sewage impact.

4.2.4 Petroleum hydrocarbons

Pollution by petroleum hydrocarbons (oils and fuel) is not an obvious problem associated with tourism, but small-scale spills may occur during fuelling of recreational vessels at sea or in marinas. Also, recreational vessels may discharge oil or oily bilge water either accidentally or knowingly.

Again, there are no studies that link the impact of petroleum hydrocarbon pollution on coral reefs directly to tourist activities, but the literature provides information on such impact in a general sense. Controlled laboratory experiments have been conducted, as well as field studies on the impact of large spills and chronic oil pollution (the latter mainly in the Red Sea). Loya and Rinkevich (1987) and Grigg and Dollar (1990) reviewed the impacts of petroleum hydrocarbons on reef corals. There is evidence that (a) chronic exposure to oil pollution is more detrimental than a single exposure (as in spills) – unless the corals are coated in oil during low tide, which is not a severe threat in the Caribbean region, and (b) that dispersants or emulsifiers used to combat spills, as well as a mixture of dispersants and oil, are more toxic to corals than the oil alone. The impacts of chronic oil pollution include higher mortality rates of corals, a decrease in reproduction, and a reduction in the settlement of coral larvae.

SUMMARY AND CONCLUSIONS

- Chronic oil pollution is more detrimental than a single exposure.
- Dispersants and emulsifiers are more toxic than oil alone.
- Chronic oil pollution increases mortality and affects reproduction and settlement.

Box 5. Summary and conclusions oil pollution impact.

4.2.5 Sedimentation

Grigg and Dollar (1990), in their review of natural and anthropogenic disturbances on coral reefs, state: “The impact of increased sedimentation is probably the most common and serious anthropogenic influence on coral reefs.” Increased sedimentation results primarily from dredging and runoff. Dredging, runoff or siltation were mentioned as one the human-related stresses on coral reef in Barbados, Bermuda, Bonaire, Costa Rica, Curaçao, Dominican Republic, Florida Keys, Grenada, Guadeloupe, Jamaica, Panama, St. Lucia, British Virgin Islands and US Virgin Islands (Rogers, 1985). Rogers (1990) associates dredging in the Caribbean with construction of hotels, condominiums, runways, roads, harbours, navigation channels, military installations, and beach replenishment. She states: “Unprecedented development along tropical shorelines is causing severe degradation of coral reefs primarily from increases in sedimentation.” Occasional concern is also expressed with inexperienced snorkellers kicking up sediment with their fins. Although this may cause a problem in localised areas, the effect has not been documented and is likely to be small compared to sedimentation resulting from dredging and runoff.

Background levels of sedimentation on reefs that are not influenced by human activities are between 1 and 10 mg per m^2 per day (Rogers, 1990). Sudden exposure to heavy sedimentation may result in burying of corals, expulsion of the symbiotic algae from the coral polyps ("bleaching"), and subsequent death. However, certain species have the ability to actively remove sediment from their tissues. Rogers (1990) summarises the results of field and laboratory studies as follows:

1) Different species have different capabilities of removing sediment or surviving at lower light levels.
2) The coral's ability to remove sediment depends on the amount and type of sediment, which covers the coral colony.
3) Sediment rejection is a function of morphology, orientation and behaviour of a coral colony.

Chronic exposure to higher concentrations of sediment can have a variety of negative impacts on corals, many of which can be attributed to reduced light levels. These include (Rogers, 1990):

1) Lower species diversity and absence of certain species.
2) Less cover by live coral.
3) Lower coral growth rates.
4) Greater abundance of branching forms.
5) Reduced coral recruitment.
6) Decreased calcification.
7) Decreased net productivity of corals.
8) Slower rates of reef accretion.

Marszalek (1981) monitored the impact of a large-scale dredging operation for beach replenishment in Miami, Florida. He distinguished three types of impact: mechanical damage, sediment loading and increased turbidity. A substantial percentage of coral colonies showed signs of stress such as partial bleaching, polyp swelling and excessive mucus secretion. He suggests that sustained increased turbidity was more detrimental than short-term sediment loading.

Van't Hof (1983) describes the effects of dredging and excavation (to construct a canal system and waterfront home sites in a limestone cliff) on the fringing reef in Bonaire. Dredging resulted in sediment loading of almost 100 times the background level, and a decrease in percent of live coral cover on the deep reef from 73% to 32%.

Hodgson (1990) determined that sedimentation inhibited settlement of coral larvae on artificial substrate in a common Indo-Pacific coral species, thus potentially affecting coral recruitment under natural circumstances.

Finally, reef degradation is also partly responsible for a decline of reef fisheries. Sedimentation can kill major reef-building corals, leading to the eventual collapse of the reef framework. The reduction in the percentage of living coral as well as the decrease in the amount of shelter that the reef provides leads to a decline in the number of reef fish and the number of species (Rogers, 1990).

SUMMARY AND CONCLUSIONS

- Increased sedimentation is considered one of the major causes of reef degradation.
- Increased sedimentation is associated with coastal development in general, of which development of tourism infrastructure and facilities is an important component.
- Sedimentation results mainly from dredging and runoff associated with construction and beach replenishment.
- The main effects of sedimentation are increased turbidity (reduced light penetration) and sediment settling on corals.
- Sediment settling on corals leads to stress, bleaching, and –in certain species- to death.
- Increased turbidity has a variety of negative impacts on corals, such as lower growth rates, reduced productivity, and reduced recruitment.
- Sedimentation can lead to changes in reef structure that impact negatively on reef fish populations.
- Developers, investors and decision makers need to be convinced of the trade-offs of stringent development guidelines and building codes as a means to reduce the negative impacts of coastal development on coral reefs.

Box 6. Summary and conclusions sedimentation impact.

4.2.6 Solid waste

There are two existing or potential impacts of solid waste disposal on coral reefs: leaching of toxic substances from landfills and dumps, which include waste from tourist resorts (this effect has not been documented), and accidental disposal of waste from resorts, recreational vessels, and cruise ships. Light plastic and aluminium items (cups, plates, bottles, bags, cans) are frequently blown into the sea by wind. The detrimental effects of plastics in the ocean are well documented (see for example Norse, 1993). In the context of coral reefs, we should mention smothering of corals by plastic bags and sheeting, entanglement of sea turtles and fishes in six-pack rings, and ingestion of plastics by sea turtles. In addition, litter and trash reduce, of course, the aesthetic aspect of the coral reef environment.

SUMMARY AND CONCLUSIONS

- Leaching of toxic substances from landfills and dumps may impact negatively on corals.
- Plastics can smother corals; some marine animals ingest plastics or become entangled in plastics.
- Litter reduces the aesthetic aspect of the coral reef.

Box 7. Summary and conclusions solid waste impacts.

4.2.7 Compounded effects

Simmons and Associates (1994), in their survey on the impact of tourism on the marine environment of the Caribbean, note that while St. Thomas and St. John, US Virgin Islands, represent one of the best examples to demonstrate that there is a definite negative impact of tourism on the marine environment, it is a compound effect and it is extremely difficult to attribute a decline in environmental quality to a specific tourist activity. They conclude: “The reefs are generally in poor condition as a result of compound effects, including increased runoff and sedimentation from construction sites, sewage pollution, anchoring and other types of recreational use.”

Bak and Nieuwland (1994) describe the decline in coral cover at two shallow depths on leeward reefs in Curacao and Bonaire, Netherlands Antilles. The decline ranged from 16 to 53% (loss of coral cover expressed as percentage of original percent cover) with little sign of recovery over the 19-year study period. In the absence of natural disturbances, the lack of recovery is ascribed to impacts of urbanization and tourism development such as increasing sewage disposal, construction at the shoreline, etc.

Connell (1997), in his literature survey of disturbance and recovery of coral assemblages, expresses concern over the lack of recovery from decline in coral cover following both natural and anthropogenic disturbances in the Western Atlantic (as compared with the Indo-Pacific region). He attributes this to the relatively small, compact nature of the Western Atlantic region, which exacerbates the effects of intense human activities, combined with high nutrient runoff and construction from increasing coastal development.

Other factors affecting recovery of coral reefs in the Western Atlantic are undoubtedly the occurrence of the white-band disease in the early eighties, which locally caused high mortality among Elkhorn and Staghorn coral (*Acropora palmate* and *A. cervicornis*), the massive die-off of the long-spined sea urchin (*Diadema antillarum*), and a reduction of herbivorous fish due to over-fishing. The lack of herbivores causes an increase in macro-algae and reduces the amount of clean hard substrate needed for coral recruitment. However, Lapointe *et al.* (1997) demonstrated that massive macro-algal overgrowth of the fore reef in Jamaica, which had been attributed to the reduced grazing due to over-fishing and the Diadema die-off, was clearly linked to increased nutrient levels and difficult to relate temporally to reduced grazing by herbivores.

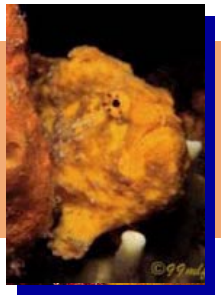
Muzik (1985), describes a dramatic decline in percent coral cover of reefs in the Ryukyu Archipelago, Japan. In the course of a decade the reefs appeared to be mostly dead or dying and the number of species decreased dramatically. The reefs had been heavily affected by predation by the Crown of Thorns starfish in 1974. Subsequent intensive development -not restricted to, but including tourism development- caused heavy sedimentation and runoff and resulted in further deterioration of the coral reefs.

4.3 Addressing the problem

Saving coral reefs is not just a matter of controlling or eliminating tourism impacts. Effects very similar to those of tourism are the result of increasing human population and development of the coastline adjacent to coral reefs in general. And these effects are not easily distinguishable from those of tourism *per se*. In addition there are natural phenomena which impact on coral reefs that also cannot always be distinguished from human impacts.

The determination of the carrying capacity of coral reefs for direct and indirect human use is extremely complex and therefore not likely to produce any meaningful guidelines in the short term. Therefore the minimisation of those impacts that *can be* controlled should be a priority. Sediment loading *can* be reduced by developing and imposing development guidelines and building codes, nutrient enrichment *can* be reduced by installing proper sewerage systems and sewage treatment facilities, physical damage *can* be reduced by installing mooring buoys, designate anchorages and increasing awareness among divers, snorkellers and recreational boaters. Some of these measures are going to be very costly or will limit development options and raise the cost of development and will therefore not be popular with decision makers and investors.

Mobilising public support through awareness building can contribute to the effective implementation of these measures.



5. ANALYSIS OF KEY ACTORS IN THE TOURISM SECTOR: LEVEL OF AWARENESS AND POTENTIAL BENEFITS FROM CHANGE IN BEHAVIOUR

Based on the analysis of tourism activities and their impacts on coral reefs, the following key actors in the tourism sector can be identified:

- The individual tourist
- Those who cater directly to the tourist
- Those who cater indirectly to the tourist

Each of these is a composite group, the elements and characteristics of which are described and analysed separately.

5.1 The individual tourist

This group can be divided into two broad categories:

a. Sun, sea and fun seekers. This group goes by a series of different names and is presumably by far the largest segment of Caribbean tourism. Cruise tourists are included in this category. Although a survey of this category was beyond the scope of this project, it was assumed that climate, quality of beaches and accommodation, as well as entertainment and shopping opportunities are the main deciding factors in the selection of their destination. It is therefore also assumed that tourists in this category are on average the least environmentally aware.

b. Discriminate travellers, travelling divers, nature/heritage tourists. The quality of the natural and cultural environment, the level of crowding and sound environmental practices at the destination, are all important criteria within this category in the selection of their destination. We are therefore assuming that this category includes the most environmentally aware tourists.

Irrespective of the level of awareness, any environmentally irresponsible or damaging behaviour among the individual tourist is usually easy to influence. Wrongdoing on the part of tourists is seldom intentional, but rather a result of negligence or ignorance. Raising awareness among this group –where needed- will therefore have a relatively high result to effort ratio.

5.2 The direct caterers

This group includes the businesses that bring the tourists to their destination and those who lodge, feed and entertain them while they are at their destination. It can be divided roughly into:

a. Travel agents, tour operators, transportation companies. It can be concluded from the available information that healthy coral reefs are important to this sector because

of the diving and snorkelling opportunities they provide, which comprises at least part of their business. The level of awareness among the clients (the tourist) as well among management and staff in the sector appears to be generally low. However, travel agents and tour operators readily identify tourism-related activities that impact negatively on coral reefs, such as motorised water sports, diving, breaking or collecting of corals, sewage disposal and construction. It was noted that these impacts are not directly related to the activities of *this* sector, but a result of the activities of other sectors. The sector also identifies clear benefits from increased awareness including ecological, financial and image-related.

b. Hotels and restaurants. Hoteliers appear to be generally aware of the importance of healthy coral reefs for a variety of reasons including: attracting snorkellers and SCUBA divers, providing shoreline and property protection, nourishing beach sand, fish production, and indicators of general environmental health. They rate healthy reefs important to very important to their businesses, even at destinations that are not primarily SCUBA diving destinations.

Hoteliers also appear to be well aware of many of the causes of reefs degradation, including sewage and solid waste disposal, runoff of pesticides and fertilizers, impacts of tourist activities including motorised boating, diver and anchor damage, walking on reefs or taking corals, and construction on or near the shoreline. The awareness among the hoteliers is generally higher than that of the guests.

Hoteliers see clear benefits from increased awareness both from a perspective of marine ecosystem protection as well as from a business/financial/marketing perspective. Some point to the relation of healthy reefs with beaches and with raising environmental awareness in general. Other derived benefits from increased awareness relate to maintaining the economic value of healthy reefs for fish production and medicinal products. In interpreting these results it should be noted that hoteliers seem to be pointing the finger mostly at others and do not see their own operation as a cause for impact on coral reefs. This implies that, although they are convinced of the benefits of increased awareness, this “increased awareness” needs to be someone else’s rather then their own.

Over the last decade there has been a tremendous change in environmental attitude among hotel operators. In part this change has come about because of higher environmental standards expected by clients, and in part because of incentives offered through the industry (such as environmental audits and “green” certifications), which in turn can give the property a competitive edge.

The major concern with the impact of hotels, however, remains the sewage disposal issue. It was not possible to confirm nor reject the 1994 and 1996 assertions that 80-90% of Caribbean hotels continue to discharge sewage into the nearshore environment without proper treatment (see section 4.2.3.2). This remains a reason for grave concern, as it is not realistic to assume that hotel properties will take costly initiatives to resolve the problem by themselves, unless the authorities approach the sewage issue in a more comprehensive and global manner. Increasing awareness in the hotel sector is unlikely to make a difference here.

There is little information on the level of awareness of Caribbean restaurants. As there are not incentives and certification programmes for restaurants, as they exist

for hotels, it can be assumed that the restaurants' main objectives will be to serve the client in accordance with the demand. Thus it remains possible that protected, undersized or out of season seafood species are being served and consumed in restaurants. Raising awareness within the restaurant sector is not expected to have significant results unless the awareness of the patrons is raised first. The greatest benefits can therefore be expected from changing the buying behaviour of the client through increased awareness.

c. Water sports operators.

This is again a diverse group, which includes the small operator who rents out a few jet skis from the beach, the fisherman who takes visitors out snorkelling or on a glass bottom boat trip, as well as the larger operators who offer SCUBA diving, snorkelling trips, day sailing, and a range of other activities. Marina operators and charter boat companies are also included in this group. The level of awareness among this group is clearly directly proportional to the relation of the activity with the coral reef. Activities that are taking place *on* the water, such as water skiing, jet skiing, wind surfing, and sailing, as opposed to those taking place *in* the water such as diving and snorkelling, are obviously less connected with coral reefs and the associated level of awareness of the caterers is expected to be less.

SCUBA diving and snorkelling operators in the Caribbean generally have a very high level of awareness. While this statement is true for those at the management level in this sector, the awareness at the level of other staff is not necessarily as high, especially in some smaller operations. Dive operators generally give thorough pre-dive briefings, which increase the level of awareness among their clients significantly. The awareness among the operators and the tourist divers depends somewhat on the type of destination; if the destination is primarily known for its diving, the level of awareness will be higher than when it is a "secondary" dive destination. Although few direct answers were received in the limited survey among this sector, it can be assumed that dive operators generally agree that reef degradation has occurred in the area of their operation; they attribute this to natural phenomena, sewage pollution and runoff from construction and development, and to a limited degree to diver damage. The tourist diver usually observes reef degradation only when they are experienced and are repeat visitors at a certain destination. Benefits of increased awareness will be both ecological and financial. In some destinations increased awareness will be most effective among government and private sector entities responsible for development, in others also among the dive operations themselves and their clients.

Operators in the marina and yachting sector feel that coral reefs are important to them because reefs protect bays and harbours where their businesses are usually located and reefs provide a tourist attraction of economic significance. They are aware of certain negative impacts of marina operations and yachting, such as anchor damage, disposal of untreated sewage and possible toxic effects of anti-fouling paints[2]. They feel that the level of awareness is high among private yacht owners and lower among chartering yachtsmen and the businesses and operators in the sector. However, some yacht charter companies give thorough briefings to their customers,

[2] The owner of a large marine store wants to see a ban on the sale of tin-based anti-fouling paint, as non-toxic alternatives are available and none of his competitors would stop the sale of such paint wihtout a ban.

which include environmental aspects. Benefits from increased awareness will be ecological as well as financial.

5.3 The indirect caterers

This last group includes those who make political decisions on tourism and tourism development, those who provide the funds to develop the tourism infrastructure, as well as those who actually carry out the development. It includes: Politicians/decision makers (and their advisors), private investors, and financial institutions, such as commercial banks and development banks.

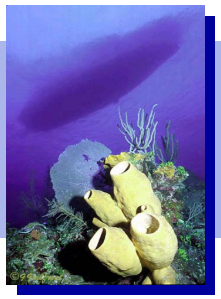
This group has perhaps not been considered one of the actors in the tourism sector with impact on coral reefs, but this is certainly an oversight. Political decisions on the development of coastal tourism and the associated private sector investments have been – and continue to be in some island states and territories- the main causes for environmental degradation. This means in some instances totally uncontrolled development, in others ill-guided or ill-planned development. In most cases it means development of tourism infrastructure that has outpaced infrastructure development in general.

Although this may be interpreted as a sign that the level of awareness among this sector is low, this is not necessarily true. The awareness may well be present, but tourism development policies in the Caribbean over the past decades have not been guided by sound environmental and ecological principles, but rather by political and economic motives. Whilst that is understandable from a political point of view, it is now beginning to backfire because of the environmental degradation and other changes that uncontrolled tourism development has brought about. Despite all the wonderful ads and deceiving brochures, destinations that have undergone environmental and cultural degradation will soon only appeal to the indiscriminate traveller (whose environmental awareness is low), while those that have opted for a more planned and controlled tourism development will be reaping the benefits of their policy in the 21st century. Almost every destination is trying to get on the eco-tourism bandwagon, irrespective of the product they are offering. The discriminate traveller of the coming decades will be increasingly environmentally conscious and will look for destinations that not only preach these values but also actually live by them.

The benefits of increased awareness among this group are potentially very high. However, this group is extremely difficult to target, and, as long as there are no clear political and economic incentives to let tourism development policy be guided by environmentally sound principles, change in awareness will not create any sustained benefits.

SUMMARY AND CONCLUSIONS			
Key actors		**Level of awareness**	**Benefits from increased awareness**
Tourists	Sun, sea and fun seekers	Mostly low	High; ecological
	Discriminate traveller	Mostly high	Moderate; ecological
Direct caterers	Travel agents, tour operators, transport companies	Mostly low	Moderate; ecological and financial
	Hotels	Mostly high	Moderate; ecological and financial
	Restaurants	Mostly low	Moderate; ecological
	Water sport operators	High in some sectors, low in others	High in some sectors, moderate in others; ecological and financial
Indirect caterers	Politicians/decision makers, private investors, financial institutions	Difficult to assess; seemingly low due to opportunistic reasoning	Potentially high, but difficult to target

Table 3. Summary and conclusions analysis of key actors in tourism sector. Analysis of key actors in tourism sector.



6. RECOMMENDATIONS ON AWARENESS CAMPAIGN: MAIN ACTIVITIES AND CORRESPONDING ACTORS TO BE TARGETED

The analysis of the impacts of tourism activities on coral reefs (section 4) and the analysis of key actors in the tourism sector (section 5) allows us to make further recommendations on the awareness campaign, and in particular, for each key actor (or sector or group) to be targeted, on the activities to be carried out and messages to be conveyed.

In order to maximise the effectiveness we suggest to target the awareness campaign only to those actors whose awareness is mostly low and for which the potential benefits from increased awareness and change in behaviour are expected to be high. These are: the individual tourist, the water sports operators, and the politicians/decision makers and investors.

6.1 The individual tourist

Based on our assumption that the largest portion of Caribbean tourists has comparatively the lowest coral reef awareness, this group should be targeted as a matter of priority. The best medium to be used is probably a combination of text and graphics, with heavy emphasis on graphics. The messages that need to be conveyed include:

- What are coral reefs and why are they important?
- What can you do as visitor to help protect coral reefs?
    a) When you go snorkelling or diving: do not stand or walk on corals, do not touch or break corals.
    b) When you go out on a boat: do not anchor in coral, do not spill any fuel or oil, dispose of litter properly and make sure no litter is blown overboard by the wind.
    c) When you are on the beach: dispose of litter properly and make sure no litter is blown into the sea by the wind.
    d) When you go shopping: do not buy any corals, shells, turtle products or black coral products (CITES, etc.).
    e) When you order food: make sure that you do not order any seafood that is either protected (turtles), under-sized or out of season (many countries have size limits and seasons for lobster and conch).

Nearly 100% of the tourists to whom we want to convey these messages will either stay in beach resorts or travel on cruise ships. The most suitable vehicles for dissemination are therefore the Caribbean Hotel Association, the Florida and Caribbean Cruise Association, the Caribbean Tourism Organization and the Caribbean Action for Sustainable Tourism.

6.2 Water sports operators and their clients

The level of awareness in this category varies between sectors and within sectors. We also find varying levels of awareness among the clients of water sports operators. In terms of developing awareness-raising tools this problem can best be addressed by developing a series of "etiquettes" that can be used to increase the awareness among both the operators and their clients. Since most of the impacts relate to physical damage from snorkellers or divers and anchoring on the one side, and to emissions of recreational vessels on the other, it seems most useful to develop etiquettes for snorkellers, divers and boaters.

The messages to be conveyed are very similar to those described under 6.1 above, but more in depth. In particular the boating etiquette must address the use of permanent moorings, discharge of sewage while anchored or moored, and the use of holding tanks. Several marine parks have developed such etiquettes. Those of the Bonaire Marine Park provide an excellent example.

The target audience for these messages include staff of water sports operators as well as their clients. The large dive operators and divers at the major diving destinations, who have the highest level of awareness, need the message much less than others. In order to have maximum effect the messages must get through to the smaller dive operators and their clients, and to water sports operators at destinations where diving is a secondary tourist activity. This complicates dissemination, as there is not a single dissemination vehicle through which all these groups can be reached. Dissemination will therefore need to take place through:

a) Local tourism boards;
b) Government agencies responsible for licensing water sports operators;
c) Local associations of dive operators, water sports operators and boat operators;
d) Marina Association of the Caribbean;
e) Bareboat charter companies.

6.3 Politicians/decision makers, private investors, financial institutions

It has been demonstrated that that coral reef degradation is caused by a number of factors, both natural and anthropogenic, which include tourist activities. There is only limited scientific evidence linking specific tourist activities directly to negative impact on reefs. However, development of the coastal zone in general -and tourism development in particular- with all its associated effects that individually can impact negatively on coral reefs, may well be the single most important factor contributing to coral reef degradation apart from "natural" impacts[3]. The complexity of the group that makes up the key actors responsible for planning, decision-making, and financing tourism development in the coastal zone, makes it quite difficult to develop effective communication tools and find appropriate distribution channels to send messages to them that will raise awareness and above all change behaviour.

[3] Natural is placed in quotation marks here, because we are not sure to what extent diseases and disasters are natural or triggered by anthropogenic factors that may have upset ecological balance.

The basic message to convey is simple and straightforward: “Coral reefs are a natural capital that, if used wisely, will yield a fixed interest in the form of sustained income from tourism and fishing. If not used wisely, the interest will go down as the value of the capital is diminished. Tourism development in the coastal zone over the past decades has been responsible for serious reef degradation because insufficient measures were taken to reduce or eliminate the negative impacts of such development. There is little time left to correct previous mistakes and save what is left of the precious capital.”

Perhaps the most effective way to convey the message is to present case studies of “failure” scenarios in graphic format (video is probably the most effective). The selection of a case study will require some further study and so will the selection of dissemination channels. However, with the “greening” of the banking sectors, development banks and commercial banks may well be good vehicles to start with. Addressing this sector in a fully effective way may well be beyond the possibilities of the current awareness building project. As a possible alternative a poster depicting a “failure” scenario, widely distributed among government agencies and lending institutions, may have some value.

7. REFERENCES

Allison, W.R. 1996. Snorkeller damage to coral reefs in the Maldive Islands. Coral Reefs 15:215-8.

Bak, R.P.M. and G. Nieuwland. 1994. Long-term change in coral communities along depth gradients over leeward reefs in the Netherlands Antilles. Bull. Mar. Sci. 56:609-16.

Bell, P.R.F. 1991. Impact of wastewater discharges from tourist resorts on eutrophication in coral reef regions and recommended methods of treatment. In: M.L. Miller and J. Auyong (eds.) 1991. Proceedings of the 1990 Congress on Coastal and Marine Tourism. Volumes I and II. (25-31 May 1990, Honolulu, Hawaii, USA). Newport, OR: National Coastal Resources Research & Development Institute. 561 pp.

Bohnsack, J.A. 1993. The impacts of fishing on coral reefs. In: Ginsburg, R.N. (ed.), 1993. Proceedings of the Colloquium on global aspects of coral reefs: health, hazards and history. Rosenstiel School of Marine and Atmospheric Science, University of Miami, FL, pp. C8-12.

Bryant, D., L. Burke, J. McManus and M. Spalding. 1998. Reefs at Risk. A Map-based Indicator of Threats to the World's Coral Reefs. World Resources Institute.

Brylske, A.F. 2000. A Model for Training Tourism Professionals in Tropical Marine Resource Management. Instructional Technologies, Inc.

Chadwick-Furman, N.E. 1997. Effects of SCUBA diving on coral reef invertebrates in the US Virgin Islands: Implications for management of diving tourism. Proc. 6th Int. Conf. Coelent. Biol. 1995:91-100.

Connell, J.H. 1997. Disturbance and recovery of coral assemblages. Coral reefs 16:S101-13.

Cortes, J. 1997. Status of Caribbean coral reefs of Central America. In: Proc. 8th Int. Coral Reef Symp. 1:335-40.

Craik, W., R. Kenchington and G. Kelleher. 1990. Coral-reef Management. In: Dubinsky, Z. Ecosystems of the World 25. Coral Reefs. Elsevier, Amsterdam, pp. 453-67.

Davis, D., V. Harriott, C. McNamara, L. Roberts and S. Austin. 1995. Conflicts in a Marine Proteceted Area: Scuba divers, economics, ecology and management in Julian Rocks Aquatic Reserve. Australian parks and Recreation, 31(!):29-35.

Dixon, J.F., L.F. Scura and T. Van't Hof. 1993. Meeting Ecological and Economic Goals: Marine Parks in the Caribbean. Ambio 22:117-125.

Epstein, N., R.P.M. Bak and B. Rinkevich. 1999. Implementation of a small-scale "no-use zone" policy in a reef ecosystem: Eilat's reef-lagon six years later. Coral Reefs 18:327-32.

Ginsburg, R.N. (ed.), 1993. Proceedings of the Colloquium on global aspects of coral reefs: health, hazards and history. Rosenstiel School of Marine and Atmospheric Science, University of Miami, FL.

Grigg, R.W. and S.J. Dollar. 1990. Natural and Anthropogenic Disturbance on Coral Reefs. In: Dubinsky, Z. Ecosystems of the World 25. Coral Reefs. Elsevier, Amsterdam, pp. 439-52.

Harriott, V.J., D. Davis and S.A. Banks. 1997. Recreational Diving and its Impact in Marine Protected Areas in Eastern Australia. Ambio 26, No. 3: 173-9.

Hawkins, J.P. and C.M. Roberts. 1992*a*. Effects of recreational SCUBA diving on fore-reef slope communities of coral reefs. Biological Conservation 62:171-8.

Hawkins, J.P. and C.M. Roberts. 1992*b*. Can Egypt's coral reefs support ambitious plans for diving tourism? In: Proc. 7th Int. Coral Reef Symp.:1007-13.

Hawkins, J.P. and C.M. Roberts. 1993*a*. The growth of coastal tourism in the Red Sea: Present and possible future effects on coals reefs. Meeting on Global Aspects of Coral Reefs: Health, Hazards and History. Rosenstiel School of Marine and Atmospheric Sciences, Miami, June 7-11, pp. N15-21.

Hawkins, J.P. and C.M. Roberts. 1993*b*. Effects of recreational diving on coral reefs. Trampling of reef-flat communities. Journal of Applied Ecology 30:25-30.

Hawkins, J.P. and C.M. Roberts. 1994. The growth of coastal tourism in the Red Sea: present and possible future effects on coral reefs. Ambio 23:503-8.

Hawkins, J.P. and C.M. Roberts. 1997. Estimating the carrying capacity of coral reefs for recreational scuba diving. In: Proc. 8th Int. Coral Reef Symp. 2:1923-26.

Hawkins, J.P., C.M. Roberts, T. van't Hof, K. De Meyer, J. Tratalos and C. Aldam. 1999. Effects of Recreational Scuba Diving on Caribbean Coral and Fish Communities. Cons. Biology 13(4): 888-897.

Hodgson, G. 1990. Sediment and the settlement of larvae of the reef coral *Pocillopora damicornis.* Coral Reefs 9(1): 41-43.

Holder, J.S. 1991. Managing the Caribbean Environment as Tourism's Resource. Paper presented at: Seminar on Tourism, Health and the Environment. Pan American Health Organization, October 31-November 3, 1991, Trinidad and Tobago.

Hubbard, D.K., E.H. Gladfelter and J.C. Bythel. 1993. Comparison of biological dn geological perspectives of coral-reef community structure at Buck Island, US Virgin Islands. In: Ginsburg, R.N. (ed.). 1993. pp. 201-7.

Hudson, J.H. and R. Diaz. 1988. Damage survey and restoration of M/V Wellwood grounding site, Molasses Reef, Key Largo National Marine Sanctuary, Florida. Proc. 6th Int. Coral Reef Symp. 2:231-236.

Island Resources Foundation. 1996. Guidance for Best Management Practices for Caribbean Coastal Tourism. Island Resources Foundation, Washington, DC, 45 pp.

Jameson, S.C., M.S.A. Ammar, E. Saadalla, H.M. Mostafa and B. Riegl. 1999. A coral damage index and its application to diving sites in the Egyptian Red Sea. Coral Reefs 18:333-9.

LaPointe, B.E., M.M. Littler and D.S. Littler. 1997. Macroalgal overgrowth of fringing coral reefs at Discovery Bay, Jamaica: bottom-up versus top-down control. In: Proc. 8th Int. Coral Reef Symp. 1:927-32.

Liddle, M.J. and A.M. Kay. 1987. Resistance, survival and recovery of trampled corals on the Great Barrier Reef. Biol. Cons. 42:1-18.

Loya, Y. and B. Rinkevich. 1987. Effects of petroleum hydrocarbons on corals. In: Human impacts on coral reefs: facts and recommendations, B. Salvat ed., Antenne Museum E.P.H.E, French Polynesia: 91-102.

Maragos, J.E., C. Evans and P. Holthus. 1985. Reef corals in Kaneohe Bay six years before and after termination of sewage discharges (Oahu, Hawaiian Archipelago). Proc. 5th Int. Coral Reef Congress, 4:189-94.

Marszalek, D.S. 1987. Sewage and Eutrophication. In: Human impacts on coral reefs: facts and recommendations, B. Salvat ed., Antenne Museum E.P.H.E, French Polynesia: 165-84.

Marszalek, D.S. 1981. Impact of dredging on a subtropical reef community, southeast Florida, USA. Proc. 4th Int. Coral Reef Symp. 1:147-53.

Meesters, E.H., M. Noordeloos and R.P.M. Bak. 1994. Damage and regeneration: links to growth in the reef-building coral *Montastrea annularis*. Mar. Ecol. Prog. Ser. 112:119-28.

Muthiga, N.M. and T.R. McClanahan. 1997. The effect of visitor use on the hard coral communities of the Kisite Marine Park, Kenya. In: Proc. 8th Int. Coral Reef Symp. 2:1879-82.

Muzik, K. 1985. Dying coral reefs of the Ryukyu Archipelago (Japan). Proc. 5th Int. Coral Reef Congress, 6:483-9.

Norse, E.A. (Ed.) 1993. Global Marine Biodiversity. A strategy for building conservation into decision making. Center for Marine Conservation. Island Press, Washington, DC.

Panos Institute and Caribbean Institute of Media and Communication (undated, but probably 1996). Improving Training and Awareness on Caribbean Coastal Tourism. In collaboration with Environmental Solutions International and International Restauration Resources. Caribbean Environment Network Project 598-0832. USAID-UNEP grant # 532-5980832-G-00-5345-00.

Pastorok, R.A. and G.R. Bilyard. 1985. Effects of sewage pollution on coral-reef communities. Mar. Ecol. Progr. Ser. 21:175-89.

Potter, B. 1996. Tourism and Coastal Resources Degradation in the Wider Caribbean. Island Resources Foundation, Washington, DC, 53 pp.

Rogers, C.S. 1985. Degradation of Caribbean and Western Atlantic coral reefs and decline of associated fisheries. Proc. 5th Int. Coral Reef Symp. 6:491-6.

Rogers, C.S., L.N. McLain and E. Zullo. 1988. Damage to coral reefs in the Virgin Islands National Park and Bioshere Reserve from recreational activities. Proc. 6th Int Coral Reef Symp. 2:405-10.

Rogers, C.S. 1990. Responses of coral reefs and reef organisms to sedimentation. Mar. Ecol. Progr. Ser. 62:185-202.

Rogers, C.S. 1991. Balancing adverse effects of marine-based tourism with marine resource protection in Virgin Islands National Park, St. John, US Virgin Islands. Unpublished paper presented at BVI National Parks Trust Symposium, August 1991.

Rogers, C.S., L.N. McLain and CR. Tobias. 1991. Damage to marine resources in Virgin Islands National Park: often out of sight, but no longer out of mind. In: M.L. Miller and J. Auyong (eds.) 1991. Proceedings of the 1990 Congress on Coastal and Marine Tourism.

Volumes I and II. (25-31 May 1990, Honolulu, Hawaii, USA). Newport, OR: National Coastal Resources Research & Development Institute. 561 pp.

Rouphael, T. 1995. Coral reefs and SCUBA divers: Identifying and assessing the effect of SCUBA divers on hard coral assemblages. Reef Research, Great Barrier Reef Marine Park Authority, Townsville, pp. 10-12.

Salvat, B. 1987. Dredging in coral reefs. In: Human impacts on coral reefs: facts and recommendations, B. Salvat ed., Antenne Museum E.P.H.E, French Polynesia: 165-84.

Scura, L.F. and T. Van't Hof. 1993. The Ecology and Economics of Bonaire Marine Park. Divisional paper 1993-44. The World Bank, Washington, DC.

Simmons and Associates. 1994. The Impact of Tourism on the Marine Environment of the Caribbean. Caribbean Tourism Organization, Barbados, 71 pp.

Smith, R.S. 1985. Reef damage and recovery after ship groundings on Bermuda. Proc. 5th Int. Coral Reef Symp. 6:497-502.

Talge, H. 1991 (?). Observations of Recreational Divers on Coral Reefs in the Florida Keys. Unpublished report prepared for The Nature Conservancy, St. Petersburg, Florida.

Talge, H. 1992. Impact of recreational divers on scleractinian corals at Looe Key, Florida. Proc. 7th Int. Coral Reef Symp. 1077-82.

Tilmant, J.T. 1987. Impacts of recreational activities on coral reefs. In: Human impacts on coral reefs: facts and recommendations, B. Salvat ed., Antenne Museum E.P.H.E, French Polynesia: 165-84.

Tilmant, J.T. and G.P. Schmahl. 1981. A comparative analysis of coral damage on recreationally used reefs within Biscayne National Park, Florida. Proc. 4th Int. Coral Reef Symp. 1:187-92.

Tomascik, T. and F. Sander. 1985. Effects of eutrophication on reef-building corals. I. Growth rate of the reef-building coral *Montastrea annularis.* Mar. Biol. 87:143-55.

UNEP. 1997. Coastal Tourism in the Wider Caribbean Region: Impacts and best Management Practices. CEP Technical Report No. 38. UNEP Caribbean Environment Programme, Kingston, Jamaica.

Van't Hof, T. 1983. De invloed van de werkzaamheden door "Flamingo Paradise" op het koraalrif. Report to the Island Government of Bonaire. Pp 12. (in Dutch).

Van Woesik, R., L.M. de Vantier and A.D.L. Steven. 1991. Discharge from tourist resorts in Queensland, Australia: coral community response. In: M.L. Miller and J. Auyong (eds.) 1991. Proceedings of the 1990 Congress on Coastal and Marine Tourism. Volumes I and II. (25-31 May 1990, Honolulu, Hawaii, USA). Newport, OR: National Coastal Resources Research & Development Institute. 561 pp.

Ward, S. and P.L. Harrison. 1997. The effects of elevated nutrient levels on settlement of coral larvae during the ENCORE experiment, Great Barrier Reef, Australia. In: Proc. 8th Int. Coral Reef Symp. 1:891-6.

Wells, S.M. 1985. What's happening to coral reefs? Part II. ICLARM Newsletter, 8(1):6-8.